

1 I CLAIM:

2 1. A method for delivering a medicine to a
3 patient's respiratory system, comprising:
4 positioning an endotracheal tube in the
5 patient's respiratory system;
6 positioning a nebulization catheter in the
7 patient's respiratory system; and
8 operating the nebulization catheter to produce
9 an aerosol of the medicine at a distal end of the
10 nebulization catheter while the endotracheal tube is
11 positioned in the patient's respiratory system.

12 2. The method of Claim 1 in which the step of
13 operating the nebulization catheter further comprises:
14 delivering a liquid medicine to a first orifice
15 located at the distal end of the nebulization catheter;
16 and
17 delivering a pressurized gas to a second
18 orifice located at the distal end of the nebulization
19 catheter in proximity to the first orifice to aerosolize
20 the liquid medicine at the first orifice.

21 3. The method of Claim 1 in which the step of
22 operating the nebulization catheter further comprises:
23 connecting a pressurized canister containing a
24 mixture of a medicine and a liquid propellant to a
25 proximal end of the nebulization catheter;
26 delivering the mixture of medicine and liquid
27 propellant through a first lumen of the nebulization
28 catheter to a first distal orifice located at the distal
29 end of the nebulization catheter; and
30 delivering a pressurized gas through a second
31 lumen of the nebulization catheter to a second orifice
32 located at the distal end of the nebulization catheter in
33 proximity to the first orifice to enhance the
34 aerosolization of the medicine emitted from the first
35 orifice.

1 4. The method of Claim 3 in which the
2 pressurized gas from the second orifice is directed
3 against the medicine and propellant delivered from the
4 first distal orifice.

5 5. The method of Claim 1 further comprising:
6 centering the nebulization catheter in the
7 endotracheal tube.

8 6. The method of Claim 1 in which the step of
9 positioning a nebulization catheter further comprises:
10 positioning a nebulization catheter through an
11 auxiliary lumen of the endotracheal tube.

12 7. The method of Claim 1 further comprising:
13 removing the nebulization catheter while
14 leaving the endotracheal tube in position in the
15 patient's respiratory system.

16 8. The method of Claim 2 further comprising
17 the step of:
18 imparting pulsation to the liquid being
19 delivered.

20 9. The method of Claim 8 in which the
21 pulsation is imparted at a frequency greater than 100
22 hertz.

23 10. The method of Claim 8 in which the
24 pulsation is applied to a proximal reservoir from which
25 the liquid medicine is supplied.

26 11. The method of Claim 8 in which the
27 pulsation is associated with the delivery of less than
28 approximately 10 microliters of liquid medicine.

1 12. The method of Claim 1 in which the step of
2 operating a nebulization catheter further comprises the
3 step of:

4 applying an electric signal to the distal end
5 of the nebulization catheter to produce the aerosol from
6 said distal end.

7 13. The method of Claim 1 further comprising:
8 providing a coaxial airflow to said distal end
9 of said nebulization catheter to constrain aerosol
10 therefrom.

11 14. The method of Claim 1 further comprising:
12 providing humidification to the patient's
13 respiratory system.

14 15. The method of Claim 1 further comprising
15 the step of:

16 balancing airflow at the distal end of the
17 nebulization catheter by withdrawing air through a vacuum
18 lumen extending through the nebulization catheter.

19 16. The method of Claim 1 in which the step of
20 positioning the nebulization catheter further comprises:
21 receiving an indication of the position of the
22 nebulization catheter relative to the endotracheal tube.

23 17. The method of Claim 16 in which the
24 indication is a tactile indication.

25 18. The method of Claim 16 in which the step
26 of receiving an indication further comprises:
27 receiving a indication of a pressure variation
28 at a distal end of the endotracheal tube as the distal
29 end of the nebulization catheter is moved past.

1 19. A method for delivering a medicine to one
2 or both lungs of a patient who is not intubated,
3 comprising:

4 positioning a nebulization catheter in the
5 patient's respiratory system; and

6 operating the nebulization catheter to produce
7 an aerosol of the medicine at a distal end of the
8 nebulization catheter.

9 20. A method of delivering an aerosol of
10 medication to a patient's lungs, comprising:

11 nebulizing the medication at a distal end of a
12 catheter located in the patient's respiratory tract, said
13 distal end of said catheter directed in a first
14 direction; and

15 directing a flow of gas at said nebulized
16 medication in a direction opposite to said first
17 direction.

18 21. The method of Claim 20 in which said first
19 direction in said nebulizing step is a distal direction.

20 22. The method of Claim 20 in which said first
21 direction in said nebulizing step is a proximal
22 direction.

23 23. The method of Claim 20 in which said
24 directing step is further characterized by:

25 directing a flow of gas from a distal end of an
26 endotracheal tube.

27 24. The method of Claim 20 in which said flow
28 of gas is an inhalation of the patient through an
29 endotracheal tube.

1 25. A method of delivering a medicine
2 selectively to a bifurcated region of a patient's
3 respiratory system, comprising:

4 positioning a catheter into a branch of the
5 patient's respiratory system that leads to a region other
6 than the region to which the medicine is to be delivered;
7 delivering an airflow through the catheter; and
8 nebulizing the medicine in the respiratory
9 system proximal of where the airflow is delivered whereby
10 a plume of the nebulized medicine is delivered to the
11 region without the catheter.

12 26. A catheter for delivering an aerosol of
13 medicine to a patient's lungs comprising:

14 a catheter shaft having a proximal end and a
15 distal end;

16 a lumen through the catheter shaft and
17 communicating at the proximal end with a port for
18 receiving a medicine in a liquid form and communicating
19 at the distal end with a distal orifice from which the
20 medicine can be discharged;

21 means for nebulizing the medicine discharged at
22 the distal orifice into an aerosol plume of particles of
23 the medicine; and

24 means for modifying the aerosol plume of
25 particles of medicine.

26 27. The catheter of Claim 26 wherein the
27 modifying means comprises:

28 a vacuum orifice located close to the distal
29 orifice from which the medicine is discharged for
30 scavenging air from the nebulized aerosol.

31 28. The catheter of Claim 26 wherein the
32 modifying means comprises:

33 means for decreasing the velocity of the
34 particles.

1 29. The catheter of Claim 26 wherein the
2 modifying means comprises:
3 means for increasing the width of the aerosol
4 plume .

5 30. A catheter system for delivering an
6 aerosol of medicine to a patient's lungs comprising:
7 a catheter shaft having a proximal end and a
8 distal end;
9 a lumen through the catheter shaft and
10 communicating at the proximal end with a port for
11 receiving a medicine in a liquid form and communicating
12 at the distal end with a distal orifice from which the
13 medicine can be discharged;
14 means for nebulizing the medicine discharged at
15 the distal orifice;
16 a flow control apparatus connected to the port,
17 said flow control apparatus comprising:
18 a flow line communicating with the port, said flow
19 line occupied by the medicine; and
20 a valve associated with the flow line to cause
21 pulsed delivery of medicine through the flow line.

22 31. The catheter system of Claim 30 in which
23 said flow control apparatus further comprises:
24 a draw back area associated with the flow line,
25 said draw back area adapted to cause a reversal of flow
26 of medicine through the flow line synchronized
27 with the pulsed delivery.

28 32. A catheter for delivering an aerosol to a
29 patient's lungs comprising:
30 a shaft comprised of:
31 an outer tubular member defining a first lumen
32 and terminating at a distal end in a first distal
33 orifice;

1 an inner tubular member defining a second
2 lumen, said inner tubular member located in the first
3 lumen and terminating at a distal end in a second distal
4 orifice;

5 a manifold connected to a proximal portion of said
6 shaft, said manifold having:

7 a first port communicating with the first lumen
8 for conveyance of a pressurized gas in an annular region
9 between the inner and outer tubular members; and

10 a second port communicating with the second
11 lumen for conveyance of a medicine;

12 said second distal orifice aligned with said first distal
13 orifice to nebulize the medicine from a distal tip of the
14 catheter.

15 33. The catheter of Claim 32 further
16 comprising:

17 a retractable pin located in said second lumen.

18 34. A catheter for delivering an aerosol of
19 medicine to a patient's lungs comprising:

20 a catheter shaft having:

21 a first lumen centrally located in said shaft
22 and adapted for conveying a medicine in liquid form;

23 a plurality of lumens peripherally located
24 around said first lumen and adapted for conveying a gas;

25 a distal liquid orifice communicating with said
26 first lumen; and

27 a plurality of distal gas orifices
28 communicating with said plurality of lumens, said
29 plurality of distal gas orifices aligned with respect to
30 said distal liquid orifice so as to nebulize a liquid
31 medicine discharged from the liquid orifice.

32 35. A catheter system for delivering an
33 aerosol therapy to a patient's lungs comprising:

1 a stand-alone nebulization catheter having a
2 distal end for insertion into the respiratory system of a
3 patient and a proximal end, said nebulization catheter
4 having:

5 a catheter shaft;

6 a gas pressurization lumen extending through
7 said catheter shaft;

8 a distal gas exit orifice communicating with
9 said gas pressurization lumen, said distal gas exit
10 orifice located at the distal end of said nebulization
11 catheter;

12 a drug delivery lumen extending along at least
13 a portion of said catheter shaft; and

14 a distal drug delivery orifice communicating
15 with said drug delivery channel, said distal drug
16 delivery orifice located in proximity to the distal gas
17 exit orifice so that gas exiting from said distal gas
18 exit orifice nebulizes a drug delivered from said distal
19 drug delivery orifice.

20 36. The catheter system of Claim 35 further
21 comprising:

22 an endotracheal tube having a ventilation lumen
23 in which said nebulization catheter extends.

24 37. The catheter system of Claim 35 further
25 comprising:

26 an endotracheal tube having a ventilation lumen
27 and an auxiliary lumen located adjacent to said
28 ventilation lumen, said auxiliary lumen having a distal
29 aperture into said ventilation lumen such that a distal
30 end of said auxiliary lumen exits into the ventilation
31 lumen close to a distal end thereof, and further in which
32 said nebulization catheter extends through said auxiliary
33 lumen.

1 38. The catheter system of Claim 35 further
2 comprising:

3 a centering apparatus located on said catheter
4 shaft close to the distal end.

5 39. The catheter system of Claim 35 in which
6 the centering apparatus has an expanded size and a
7 reduced size and the centering device assumes the
8 expanded size when deployed in an airway passage.

9 40. The catheter system of Claim 35 in which
10 the centering apparatus includes more than one expanded
11 size.

12 41. The catheter system of Claim 35 in which
13 the centering apparatus has an expanded size that can be
14 adjusted after deployment.

15 42. The catheter system of Claim 35 in which
16 said centering apparatus comprises gas centering jets.

17 43. The catheter system of Claim 35 in which
18 the nebulization catheter includes a valve located in at
19 least one of the lumens.

20 44. The catheter system of Claim 43 in which
21 the valve is located in at least one of the distal
22 orifices.

23 45. The catheter system of Claim 43 in which
24 the valve is controlled from the proximal end of the
25 nebulization catheter.

26 46. The catheter system of Claim 43 in which
27 the valve is actuated from the distal end of the
28 catheter.

1 47. The catheter system of Claim 43 in which
2 the valve is formed by an elastically closed tip.

3 48. The catheter system of Claim 35 further
4 comprising a safety stop on a proximal portion of the
5 catheter shaft.

6 49. The catheter system of Claim 35 further
7 comprising:

8 graduated markings on said catheter shaft.

9 50. The catheter system of Claim 35 further
10 comprising:

11 luer lock connectors on proximal ports
12 communicating with said gas pressurization lumen and said
13 drug delivery lumen.

14 51. The catheter system of Claim 35 further
15 comprising:

16 self-sealing proximal ports communicating with
17 said gas pressurization lumen and said drug delivery
18 lumen.

19 52. The catheter system of Claim 35 further
20 comprising:

21 means for clearing flow blockages at the distal
22 end of the catheter.

23 53. The catheter system of Claim 35 further
24 comprising:

25 a retractable pin located in at least one of
26 said lumens.

27 54. The catheter system of Claim 35 further
28 comprising:

29 a stripe on said catheter shaft.

1 55. The catheter system of Claim 35 further
2 comprising:

3 a baffle located at the distal end of the
4 nebulization catheter in front of the orifices.

5 56. The catheter system of Claim 35 in which
6 said catheter shaft includes a third lumen extending
7 therethrough; and

8 a fiber optic scope extending through said
9 third lumen.

10 57. The catheter system of Claim 35 wherein at
11 least a portion of said shaft surrounding said drug
12 delivery lumen is formed of a low compliance material so
13 that flow control at said distal drug delivery orifice of
14 a fluid delivered through said drug delivery lumen is
15 more responsive to flow control at a location proximal
16 thereto.

17 58. The catheter system of Claim 35 further
18 comprising:

19 a vibrating material located close to said
20 distal orifices.

21 59. The catheter system of Claim 58 in which
22 said vibrating material is a piezoelectric material and
23 further in which said piezoelectric material is connected
24 to at least one electrical conductor that extends through
25 said catheter shaft.

26 60. A suction catheter for use with an
27 endotracheal tube, said suction catheter sized to be
28 received in a ventilation lumen of the endotracheal tube,
29 said suction catheter having an aspiration lumen for
30 removing mucous from the respiratory tract of an
31 intubated patient, said suction catheter further
32 including:

1 a gas pressurization lumen extending through a
2 wall of said suction catheter adjacent to said aspiration
3 lumen;

4 a distal gas exit orifice communicating with
5 said gas pressurization lumen, said distal gas exit
6 orifice located at the distal end of said suction
7 catheter;

8 a drug delivery lumen extending through the
9 wall of said suction catheter adjacent to said aspiration
10 lumen;

11 a distal drug delivery orifice communicating
12 with said drug delivery channel, said distal drug
13 delivery orifice located in proximity to the distal gas
14 exit orifice so that gas exiting from said distal gas
15 exit orifice nebulizes a drug delivered from said distal
16 drug delivery orifice.

17 61. The suction catheter of Claim 60 in which
18 said distal gas exit orifice and distal drug delivery
19 orifice are oriented proximally toward a distal suction
20 opening communicating with said aspiration lumen.

21 62. The suction catheter of Claim 60 in which
22 said distal gas exit orifice and distal drug delivery
23 orifice are oriented radially relative to an axis of said
24 suction catheter.

25 63. A method of forming a catheter for
26 nebulizing a liquid with a gas, the catheter having
27 closely spaced distal orifices sized and spaced apart
28 with low tolerances, comprising the steps of:

29 providing a relatively large size multilumen
30 extruded polymer tubing;

31 heating a portion of the tubing to a transition
32 temperature of said tubing;

33 drawing down said portion of tubing to form a
34 tapered section with a draw down ratio in the range

1 between 2 to 1 and 20 to 1 such that the lumens are
2 increasingly closely spaced in said tapered region; and
3 forming a plurality of orifices at a distal end
4 of said tapered section, said plurality of orifices being
5 sized to nebulize a liquid delivered through one of said
6 lumens to form an aerosol with a gas delivered through
7 another of said lumens.

8 64. The method of Claim 63 the which the step
9 of forming a plurality of orifices further comprises:
10 cutting a distal end of the tapered section.

11 65. The method of Claim 63 further comprising:
12 cutting the tubing to size to form a shaft
13 portion of the nebulization catheter.

14 66. The method of Claim 63 further comprising:
15 exposing a portion of said tubing to high
16 energy radiation.

17 67. The method of Claim 63 in which said
18 catheter is for use in the respiratory system.

19 68. The method of Claim 63 in which the step
20 of heating further comprises:
21 heating the tubing to a temperature between a
22 melt state and a glass state of said tubing.